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METHOD AND DEVICE FOR PRETREATING VIA THE
CENTRIFUGING OF SAMPLES

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10 The present invention concerns a method and a device for pretreating
via the centrifuging of blood samples contained in tubes prior to being
introduced into an automatic analysis device.

Generally speaking, so as to analyse them, the tubes of samples are
normally arranged in lines inside containers or sample racks, each containing
15 several tubes (usually five) axed vertically in a longitudinal vertical median
plane of the container.

These containers include a base in which a transversal prismatic cavity
is made having a T-shaped section (or round tail).

They are transported inside baskets whose bottoms are equipped with
20 rails having profiles complementary to that of said cavities.

They are introduced into these baskets by being placed side by side so
as to form a line orientated perpendicular to their longitudinal axis and by
moving them in translation in the direction of the line so as to have them slide
inside the baskets where they are supported and guided by means of the
25 engaging of the rail in the cavities of the containers.

The transfer of the containers of the baskets where they are located to
the analysis robot is carried out by means of a mobile thruster in the axis of
the rail and whose step by step movements are ensured by a mechanism
comprising a backgeared motor which drives a pinion which gears with a rack
30 axed perpendicularly to the rail and on which the thruster is rendered integral.

This thruster is able to move the containers along the rail so as to bring the final container of the line onto a belt conveyor axed perpendicular to the rail which feeds the analysis robot.

In the case where it is desired to carry out certain types of analysis, such as hemostasis tests on blood samples, it is necessary to centrifuge these samples before conducting analysis in the analysis robot.

To this effect, centrifugal machines are used including a rotor with an axis of vertical rotation to the periphery from which a plurality of boats are mounted tilting and able to each contain one or several containers of tubes of samples.

Once the containers are placed in the boat (in a vertical position), the rotor is driven in rotation. Because of this, under the effect of the centrifugal force, the boats are placed horizontally and the samplings contained in the tubes undergo a centrifuging.

Of course, this centrifuging process can only be carried out if the unit constituted by the rotor, the boats and the containers provided with their tubes is correctly balanced.

In fact, if this unit is not correctly balanced, its rotation generates a vibratory moment which is no longer able to be tolerated beyond a specific threshold.

Owing to this, the centrifugal machine comprises a safety system which stops the centrifugal machine when this vibratory moment exceeds said threshold.

So as to take account of this problem, it is therefore necessary to provide prior to each centrifuging stage a balancing stage.

This stage can be carried out manually by adding test tubes in the incomplete containers. However, this solution involves the continuous presence of an operator at the centrifuging station. In fact, this balancing stage is difficult to make automatic and usually involves access to the containers already placed in the boats of the centrifugal machine which makes it necessary to intervene concerning the design of the centrifugal machine.

Thus, the object of the invention is to provide a centrifuging device in which feeding the centrifugal machine with containers, the balancing of the centrifugal machine and the transfer of the containers from the centrifugal machine to the analysis robot are carried out automatically with the aid of
5 relatively simple reliable and inexpensive elements.

To this effect, the invention provides a method including the following operational phases :

- the detection of the presence of tubes inside the containers at the time the latter are transported to the centrifugal machine ;
- 10 - the detection of a foreseeable lack of balance of the centrifugal machine and when this detection reveals to the presence of this lack of balance due to the presence of an incomplete container ;
- the simulation of the load of the centrifugal machine incorporating the incomplete container ;
- 15 - the selection of a balancing container according to the number of tubes missing in the incomplete container or an odd number of containers ;
- the determination of the boat of the centrifugal machine inside which the balancing container needs to be placed so as to obtain a
20 good balancing of the load ;
- the placing of this container in said boat in the place of the samples container which should to be already there, thus provoking a shift in the order for introducing the sample containers in the centrifugal machine ;
- 25 - the replacing of the balancing container onto its storage area during the transfer of the sampling containers to the robot once centrifuging has been carried out.

As regards the selection of the balancing containers, the invention simplifies this operation by being based on the fact that the centrifugal
30 machine tolerates a lack of balance slightly exceeding the lack of balance brought about by the absence of one tube out of five normally present in the

container. Because of this, it is enough to provide only two types of balancing containers respectively corresponding to one container containing two tubes and one container containing four tubes so as to compensate all the possible lacks of balance.

5 One embodiment of the invention is described hereafter and is given by way of non-restrictive example with reference to the accompanying drawings on which :

Figure 1 is a diagrammatic perspective view of a tube container ;

Figure 2 is a diagrammatic vertical section of a centrifugal machine ;

10 Figures 3 to 6 are top views of a centrifuging device according to the invention at various stages for the functioning of said device ;

Figures 7 and 8 are diagrammatic axial sections illustrating the operating principle of the device for feeding the centrifugal machine associated with the detector detecting the presence of tubes in the containers ;

15 Figures 9 and 10 are flow charts of the programme used to balance the centrifugal machine.

In this example, the device of the invention is intended to pretreat by means of centrifuging the samples contained in tubes T placed in containers P, such as the one shown on figure 1 prior to the introduction of these containers
20 P one by one into an analysis robot AA.

This analysis robot AA may comprise, as described in the patent FR No 97 07 751 filed in the name of the Applicant, a pipetting area in which the tubes of samples T, placed in their containers P and previously identified, are successively brought and above which a pipette head moves.

25 During the process preceding the phase for carrying out tests in the analysis robot AA, the containers P containing the tubes (sealed) of samples (for example blood samples) are placed in the boats NA of a centrifugal machine CE, such as the one illustrated on figure 2 where they are subjected to centrifuging. Throughout this process, the tubes T are kept inside the
30 containers so as to avoid being handled.

On leaving the centrifugal machine CE, the containers containing the tubes are brought into specially designed baskets placed in a container distributor DP₁ which equips the feeding station PA₁ of the containers P at the analysis robot AA.

5 The containers P used may consist of the container P shown on figure 1 and having a general parallelepiped shape with bevelled vertical edges. This container comprises a base E provided with a ribbing delimiting a transversal prismatic cavity CP having an approximately C-shaped section or round tail and intended to cooperate with a guiding rail RG having a complementary T-
10 shaped section.

This rail RG is provided at the bottom of the baskets PA₁, PA₂ and in the transfer areas in which the containers P are moved in translation perpendicular to their axis of symmetry.

The upper portion of the container P here comprises five vertical
15 cylindrical alveoles A₁ to A₅ opened at the level of the upper face of the container and intended to receive five respective tubes T.

Figures 3 to 7 show the path followed by the containers P in the pretreating device from a station PA₂ for feeding this device in which the containers P are placed in baskets as far as the feeding station of the analysis
20 robot where these containers are again brought together in a basket PA₁ associated with a one-by-one container distributor DP₁.

In these figures, the centrifugal machine CE has been shown in the shape of a rectangular block inside which an extraction feeding area AL is also represented by a block in which the containers can be successively introduced
25 or extracted by means of a grasping mechanism MP.

The feeding station PA₂ is placed along one lateral side CL₁ of the centrifugal machine CE situated opposite the feeding station PA₁ of the robot AA, these two stations PA₁, PA₂ being approximately adjacent to the front side CA of the centrifugal machine CE.

It is equipped with a mobile thruster PM_1 in translation along the lateral side CL_1 and driven by a device introducing a motor M_1 which drives a pinion geared onto a rack CR_1 .

5 The purpose of this thruster PM_1 is to extract the containers P contained in the baskets situated in the feed station PA_1 , to bring them into a storage area AS_1 adjacent to a belt conveyor BT driven by a motor M_2 which runs parallel to the rear side CP of the centrifugal machine CE and thus perpendicular to the displacement axis of the thruster PM_1 .

10 This belt conveyor BT transports one by one the containers P pushed by the thruster PM_1 to a grasping area in which the grasping mechanism MP takes them so as to bring them to the feeding area AL of the centrifugal machine CE where they are placed in the boats NA . The belt conveyor BT further allows the transportation of the thrusters P extracted from the centrifugal machine CE by the grasping means to a transport area situated on
15 the lateral side CL_2 of the centrifugal machine adjacent to the feeding station PA_2 of the robot AA . This transport area introduces a thruster PM_2 able to move perpendicular to the direction of running off of the belt conveyor BT so as to transfer via a translation movement the containers P brought by the belt conveyor BT into the basket equipping the feeding station PA_1 . To this effect,
20 the thruster PM_2 is activated by means of a mechanism introducing a gear driven in rotation by a motor M_3 which gears with a rack CR_2 .

The distribution of the containers P contained in the basket of the feeding station PA_1 inside the analysis robot AA is effected with the aid of an endless belt CS mounted on rollers axed vertically, one of said rollers being
25 driven in rotation by a motor. This belt CS , placed at the end of the basket parallel to the containers P , bears a drive dog able to be geared on the extremity of the containers P and situated opposite the intake opening of the analysis robot AA .

As shown on figure 3, the centrifugal machine CE could
30 advantageously include a rotor RV with a vertical axis driven by an electric motor M_4 and comprising a rotary support element PS provided with a

plurality of pairs of coaxial journals TC on each of which it is possible to suspend oscillating boats NA designed to receive the containers P at the rate of one or several containers per boat. In this example, the means to ensure suspension and allow rotation of the boats NA consists of half bearing DP
5 open towards the bottom in which the journals TC are engaged so that these boats NA can be easily extracted by lifting them up.

The whole of this mechanism is housed inside a box closed at its upper portion by a plate PL which includes at the level of said feed zone an orifice OE used for extracting the boats NA.

10 To this effect, the centrifugal machine includes an extraction mechanism consisting of a support element mounted on the rod T1 of a jack placed below the orifice OE and intended to lift up the boats NA up to a level situated above the plate PL so that the containers P contained in the boats NA can be picked up by the grasping means MP, or conversely these grasping
15 means MP can be laid with new containers P.

At the time they are lifted up, the boats NA can be rendered integral temporarily on the extremity of the support element with the aid of permanent magnets.

As mentioned previously, the aim of the invention is to automatically
20 resolve the problems of the balancing of loads of the rotor so as to obtain a fully automated functioning of centrifuging, as well as the various transfers of the containers to the feeding station of the robot.

To this effect, the invention provides a device for detecting the presence of tubes inside the containers during their path from the feeding station PA₂ up
25 to the belt conveyor BT.

This detection device DD here includes a row of detection jacks VD axed perpendicular to the displacement axis of the containers P and mounted on a structure moving in translation above the containers P from the station PA₂ as far as the belt conveyor BT. (The detection of the presence of a tube
30 being obtained when the rod of the jack stopped on the tube is unable to carry out a complete travel).

Driven is provided by a mechanism introducing a motor M_4 driving a pinion which gears on a rack CR_3 .

The mechanism for picking up and transporting the containers between the belt conveyor BT and the feeding area AL of the centrifugal machine CE is
5 integral with the structure bearing the detection jacks VD.

In accordance with the invention, this device introduces a processor which controls all the motors M_1 to M_4 of the belt distributor CS, as well as the functioning of the centrifugal machine so as to obtain the following operating sequence.

10 Initially, a basket containing the containers (in this instance four) is placed in the feeding station PA_2 , the thruster PM_1 being in a pushed back position (fig. 3).

The thruster PM_1 is then activated and pushes back the four containers P into a storage area adjacent to the belt conveyor BT (fig. 4). The presence
15 detection device DD then moves above the containers P and, for each container P, detects the presence or absence of the tubes T contained in this container P. The information relating to these presences or absences is sent to the processor.

At the end of detection, the presence detector and accordingly the
20 grasping mechanism are arranged above the belt conveyor BT (fig. 4).

This processor conducts simulations by means of the information originating from the device DD so as to be able to allocate each of the thrusters PM to a boat of the centrifugal machine CE so as to balance the latter. In the case where the processor observes a lack of balance, it is able to
25 replace one of the thrusters with a balancing thruster PE_1 , PE_2 .

As mentioned previously, in the case where the tolerance permitted by the centrifugal machine CE is one tube per container, it is possible to only use two different types of balancing containers PE_1 , PE_2 corresponding respectively to one container including four tubes and one container including
30 two tubes.

These two containers PE_1 , PE_2 are placed on a storage area of the plate of the centrifugal machine and pushed by two respective jacks to a location accessible by the grasping mechanism MP (fig. 8).

Once the processor has allocated to each of the boats NA a container P
5 (possibly a balancing container), the thruster PM_1 pushes the containers P one by one onto the belt conveyor BT. Each container is then picked up by the grasping mechanism MP which transports it and introduces it into the boat NA located above the orifice OE (figs 5 and 7).

Once a thruster PM has been introduced into a boat NA, the boat NA is
10 lowered again by the jack V so as to be again suspended from the journals TC of the support element PS. The rotor RV then rotates so as to bring the next boat NA determined by the processor (virtual rotor) to the right of the orifice OE. The jack V can then lift up this boat NA so as to have it pass through the orifice OE up to a position in which it is able to receive a container P which
15 has been allocated to it by the processor.

Once all the boats NA are provided with containers P, the centrifugal machine CE carries out a centrifuging stage.

Via an inverse process, the centrifugal machine CE is unloaded. To this effect, the boats NA are successively lifted up by the jack V so as to present
20 the container(s) P they contain at the grasping mechanism MP. This mechanism brings the container P back onto the conveyor belt BT or, when it involves a balancing container, onto the storage area.

The containers P brought back onto the belt conveyor BT are brought one by one to the right of the thruster PM_2 which pushes them back onto the
25 basket PA_1 situated in the feeding area of the robot AA. These containers P are then moved into the robot by the belt CS.

Figures 9 and 10 show the various stages carried out by the processor so as to determine the positioning of the containers inside the centrifugal machine.

30 So as to determine this positioning, the processor implements the positioning algorithm shown on figure 9 which includes first of all the

construction of a virtual rotor (block B₁) containing the containers P in which the presence of the tubes T has been detected by the presence detectors, followed by the calculation of the optimum arrangement (block B₂). The processor next calculates the unbalance of this arrangement and determines if this unbalance is correct or not (for example if it is less than 20 grams) (block B₃).

If the unbalance is correct, the balancing treatment ends (block B₄).

On the other hand, if the unbalance exceeds the fixed limit (here 20 grams), the processor determines if the centrifugal machine is full (block B₅).

10 If there is a place available, the processor adds a balancing container to the virtual rotor (block B₆) and then it calculates the optimum arrangement (block B₇). If the new unbalance of the rotor is correct (less than the limit) (block B₈), the balancing treatment ends. (block B₄). If the unbalance of the rotor exceeds the limit (block B₈), the processor eliminates the balancing container (block B₉) and then determines if there is a container able to be eliminated (block B₁₀). If this is not the case, the processor ends the treatment and triggers an error signal signifying that balancing is impossible (block B₁₁). If there is a container able to be eliminated (block B₁₀), the processor eliminates the final container of the virtual rotor (block B₁₂) and calculates the optimum arrangement (block B₁₃).

If the unbalance of the rotor is outside the limit (block B₁₄), the processor returns to the stage for adding a balancing container (block B₆). On the other hand, if the unbalance is correct, the balancing treatment ends (block B₄).

25 If, during finding if the centrifugal machine is full (block B₅) the virtual rotor is full, the processor moves directly to the determination stage if there exists a container able to be eliminated (block B₁₀).

The stage for calculating the optimum arrangement provided on the algorithm of figure 9 (blocks B₂ and B₇) can be carried out in accordance with the algorithm of figure 10 which successively includes the calculation of the

unbalance of the rotor (block B₂₅), the determination of the optimum rotor, as well as the optimum unbalance (block B₂₆).

The processor then determines if the unbalance is lower than a predetermined threshold (block B₂₇) and lower than the optimum unbalance
5 (block B₂₈).

If the unbalance is lower than the threshold, the search for the optimum rotor ends (block B₂₈). If the unbalance is lower than the optimum unbalance (block B₂₈), the system determines the optimum rotor and the optimum unbalance (block B₂₉) and if there still exists a possible permutation (block
10 B₃₀). If the unbalance were lower than the optimum unbalance at the block B₂₈, the system passes directly to the block B₃₀.

If no permutation is possible, this means that all the permutations have been scanned and the search for the optimum rotor ends (block B₂₈). If a permutation is possible, the system carries out the permutation (block B₃₁) and
15 then calculates the unbalance of the rotor (block B₃₂) and returns to the block B₂₇ for a new sequence.